International Journal of Wetlands Ecosystem & Environmental Restoration
Vol. 2, Issue, 1, pp.1-9, 2025
https://insight.ecorightfoundation.org/authors-guideline/
https://insight.ecorightfoundation.org/current-volumes/

Insight Ecoright: IE-WEER
IE-WEER [P] - ISSN: 2971 - 5660
[E] - ISSN: 2971 - 7183

RESEARCH ARTICLE

ASSESSMENT OF CASSAVA PEELS (WASTE) AND POULTRY MANURE AS SOIL ORGANIC AMENDMENTS AND THEIR EFFECTS ON THE GROWTH AND YIELD OF *Abelmoschus esculentus* L. Moench

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Authors' contributions
This research was carried out in collaboration among all authors. **AN** and **OFNC** collected the scientific data and wrote the manuscript. While **OPC** revised and edited the manuscript. Literature research was conducted by **AN**. All authors read and approved the final manuscript.

ABSTRACT

Intensive cultivation, excessive fertilizer application, and poor cropping practices contribute to soil nutrient depletion. This study was aimed at assessing the effectiveness of cassava peels (waste) and poultry manure on the growth of *Abelmoschus esculentus*. A Completely Randomized Design (CRD) was adopted. Homogenized soil samples of 2 kg were placed into planting bags and divided into seven treatment groups of: 2kg/CPL1, 2kg/CPL2, and 2kg/CPL3, treated with 100g, 200g, and 300g (cassava peel waste), respectively; and 2kg/PLM1, 2kg/PLM2, and 2kg/PLM3, treated with 100g, 200g, and 300g (poultry manure), respectively. The control group (CCPL) received neither of the treatment. Chemical and morphological properties were analyzed at intervals. The results CPL treatments revealed the highest plant heights, with 7.96 ± 0.89a (CPL1; 100g) and 26.00 ± 0.866a (CPL2:200g) at 2 and 4 weeks, respectively. The highest number of leaves, leaf length, and leaf width were recorded at 4 weeks, with 13.6 ± 1.15a (CPL3: 300g), 10.30 ± 1.90a, and 12.56 ± 0.40a. The CPL2 treatment yielded the highest mean potassium (K), magnesium (Mg), and sodium (Na), while CPL3 showed the highest phosphorus (P) levels. The poultry manure treatment, had the highest plant heights at 7.66 ± 2.25a (PLM1:100g) at 2 weeks and 17.6 ± 2.25a at 4 weeks. The greatest number of leaves, leaf length, and leaf width were at 300g poultry manure treatment in 2 and 4 weeks. Soil nutrients such as K and Na were highest in PLM3, while Mg and P were highest at PLM2. Nitrogen (N) levels peaked in PLM2 and PLM3. In conclusion, both poultry manure and cassava peel wastes are effective organic amendments. Their effectiveness is concentration-dependent, making it crucial for farmers to consider appropriate application rates. This research highlights the potential of these amendments as sustainable, eco-friendly alternatives to synthetic fertilizers.

Key Words: *Abelmoschus esculentus, Soil, amendment, cassava peels, poultry manure*

Citation: ***Amadi, N., Okubor, P.C. and Okogbule, F.N.C.*** **(2025).** Assessment of cassava peels (waste) and poultry manure as soil organic amendments and their effects on the growth and yield of *Abelmoschus esculentus* L. Moench. *INSIGHT ECORIGHT: International Journal of Wetlands Ecosystem & Environmental Restoration*, Vol. 2 (1):1-9.

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Article History:
Received 14TH November.2024
Received in revised form: 14TH January, 2025
Accepted 25th January, 2025
Published online: 28th January, 2025

1.1. INTRODUCTION

Soil, as a non-renewable and vital resource, is fundamental to the functioning of ecosystems and the sustainability of human life. It provides a wide array of ecosystem services that are essential for the survival of plants, animals, and humans alike. Soil acts as a critical medium for plant growth, providing the necessary nutrients, water, and support for plant roots. These plants, in turn, sustain food chains and provide raw materials, fiber, and fuel (Naeem *et al.*, 2018; Amoakwah *et al.*, 2020). Furthermore, soil also performs several crucial ecological functions. It regulates the flow of water, acting as a natural filter that removes contaminants and regulates the release of water to plants and groundwater. This filtration function helps maintain water quality and contributes to the overall health of aquatic ecosystems. Additionally, soil plays a vital role in the carbon cycle by storing large amounts of carbon in the form of organic matter. This carbon sequestration helps mitigate the effects of climate change by reducing the concentration of greenhouse gases in the atmosphere (Amoakwah *et al*., 2020). Intensive cultivation, excessive fertilizer application, and poor cropping practices have become common in modern agriculture, driven by the need to maximize short-term crop yields. However, these practices contribute significantly to soil degradation, which diminishes long-term productivity, disrupts ecosystems, and ultimately threatens food security. This farming culture depletes essential soil nutrients faster than they can be naturally replenished. Monocropping, or growing the same crop repeatedly on the same land, exacerbates this depletion, leading to nutrient imbalance and reduced soil fertility (Naeem *et al*., 2018). Additionally, frequent tilling and ploughing break down soil structure, making it more susceptible to erosion and compaction. Compacted soil reduces water infiltration, limits root growth, and disrupts oxygen exchange, all of which negatively affect plant health and other living organisms (Gregory *et al*., 2015).

Poor cropping practices, such as the removal of crop residues, indiscriminate ploughing, and open burning, prevent the natural replenishment of SOM, which is essential for nutrient cycling, soil structure, and water retention. Low SOM levels decrease soil biodiversity, disrupt microbial communities, and weaken the soil's ability to support plant life (Lal, 2015). Overuse of synthetic fertilizers disrupts the natural nutrient cycle, leading to nutrient imbalances in the soil. This can cause acidification, salinization, and the buildup of toxic elements. Additionally, nutrient runoff from over-fertilization contaminates water bodies, causing eutrophication and harming aquatic ecosystems (Haider *et al*., 2021). This pressing situation calls for the development and implementation of sustainable agricultural strategies that prioritize soil conservation, maintain ecosystem health, and ensure secure food production for future generations.

In addition to strategies like cover cropping, conservation tillage, balanced fertilization, and crop rotation (Farmaha *et al*., 2022), soil quality can be enhanced through the application of soil amendments (Guo, 2020). Soil amendments consist of materials derived from various processes aimed at improving soil productivity and overall quality (Amadi *et al.,* 2023). These amendments are categorized into organic and inorganic materials (Kamali *et al*., 2022). Adding organic materials, such as compost, manure, or biochar, replenishes SOM, enhances soil structure, and increases nutrient retention. Organic matter also promotes microbial diversity, which is essential for nutrient cycling and soil health (Kamali *et al.*, 2022).

Abelmoschus esculentus, commonly known as okra, is a versatile and multipurpose plant with wide-ranging applications. Its leaves, seeds, flowers, fruits, and stems are all edible, offering numerous food, non-food, and medicinal uses. Okra is particularly valued for its rich nutritional profile and culinary versatility, making it a staple in many global cuisines. In addition to its common use as a vegetable, various parts of the plant are utilized for medicinal and industrial purposes, such as in the production of mucilage, which has both health and industrial applications (Diaz *et al*, 2007). In Nigeria, okra is primarily cultivated during the rainy season, though it can be grown year-round with the help of irrigation systems, ensuring a consistent supply throughout the year (Donn *et al*., 2014). The plant thrives in soils that are well-moistened and well-drained, typically benefiting from the addition of organic matter or fertilizers before planting. These practices enhance soil fertility, providing essential nutrients that boost crop yield and overall production quality. This makes okra a highly adaptable and resilient crop in Nigerian agriculture, capable of thriving in various ecological zones. Okra's significance in Nigeria cannot be overstated. It is one of the leading vegetable fruits in the country, widely cultivated across various regions. Its importance is evident not only in the substantial land area dedicated to its cultivation but also in its economic value. The crop plays a critical role in the Nigerian market, contributing to the agricultural economy through both local consumption and export potential. Furthermore, okra is integral to numerous Nigerian culinary traditions, featuring prominently in a variety of local dishes and traditional recipes (Kang *et al*., 2022). Its market value is enhanced by its inclusion in daily meals, making it an essential part of the nation's food system and an important contributor to food security.

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Received 14TH November.2024
Received in revised form: 14TH January, 2025
Accepted 25th January, 2025
Published online: 28th January, 2025

2.0. MATERIALS AND METHODS

2.1 *Study Area*

The research was conducted at the Rivers State University Botanical Farm situated at coordinate's latitude N 4°47'51.96" and longitude E 6°58'50.93" in the heart of Nigeria's Niger Delta region. This area is characterized by its distinctive tropical climate, which supports a variety of agricultural activities. The climate in this region is marked by two main seasons: the wet season and the dry season. The wet season typically spans from April to September, with annual rainfall ranging from 2,400 mm to 4,000 mm, providing ample moisture necessary for the growth of a wide range of crops. The region experiences high humidity during this period, which significantly influences agricultural productivity. The dry season, which occurs from October to March, is characterized by lower rainfall and higher temperatures, creating a contrasting environmental condition that also affects crop growth and development. This seasonal variation in weather patterns plays a critical role in determining the planting and harvesting cycles, influencing the types of crops that can be cultivated throughout the year in this region. The edaphic condition is characterized by well-drained soils typical of the Niger Delta, making it an ideal location for agricultural research and experimentation.

2.2 *Sources of materials and Processing*

Cassava peels (Plate 1) were sourced from Omuoda, Aluu, in the Ikwerre Local Government Area, a region known for its cassava cultivation. The peels were obtained after the cassava tubers were processed for consumption. To prepare them for analysis, the peels were sun-dried for one week to reduce moisture content, thereby enhancing their preservation. Following the drying process, the peels were carefully ground into a fine powder to facilitate uniformity in the sample. The ground cassava peels were then transported to the laboratory for further analysis to determine their nutrient composition, providing essential data on their potential as a valuable organic input for soil fertility enhancement.

Poultry manure (Plate 2) was sourced from a local poultry farm in Omuoda, Aluu, Ikwerre Local Government Area. Upon collection, the poultry droppings were air-dried for several hours to reduce excess moisture and prevent the growth of harmful pathogens. After drying, any large, coarse particles were manually sieved out to ensure a fine, uniform texture. This prepared manure was then taken to the laboratory for a comprehensive analysis to ascertain its nutrient composition (Table1). The findings from this analysis are critical for understanding the nutrient content of poultry manure, which can be used as a natural fertilizer to improve soil fertility and support sustainable agricultural practices.

Abelmoschus esculentus L. Moench (NKOKO, 195) was obtained from National Horticultural Research Institute (NIHORT), Idi-Shin Ibadan, Nigeria (Plate 3).

Plate 1: Cassava Peels during Processing at Omuoda, Aluu.

Plate 2: Poultry Manure at a Local Poultry

Table 1. Baseline analysis of cassava peel and poultry manure

S/N	Sample identify	Nitrate (mg/L)	Phosphorus (mg/L)	K (mg/L)	Mg (mg/L)	pH (mg/L)	Na (mg/L)
1	Cassava peel	1.30	2.97	248.30	109.134	5.40	544
2	Poultry manure	4 70	1.69	2.50	0.25	6.20	32

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Received in revised form: 14TH January, 2025
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Published online: 28th January, 2025

Plate 3: ***Abelmoschus esculentus.*** **(Okra)**

2.3. *Soil Collection and Processing*

Soil samples were collected from the agricultural farmland at Rivers State University, located at coordinates latitude N 4°47'51.96" and longitude E 6°58'50.93" in the Niger Delta region. The soil was carefully collected from various representative spots within the farmland to ensure a comprehensive sample. To prepare the samples for analysis, the collected soil was sieved through a 2mm mesh to remove large particles, debris, and impurities, leaving behind a fine, homogenous soil sample. This finely sieved soil was then sent to the laboratory for baseline analysis. The primary objective of the analysis was to assess the chemical and physical properties of the soil, including nutrient levels, pH, texture, and other essential factors (Tables 2 &3). The results from this baseline analysis provide valuable insights into the soil's fertility status and help inform appropriate management practices for optimal crop production in the region.

Table 2. Baseline Analysis of Soil Chemical Properties

S/N	Sample identify	Nitrate (mg/L)	Phosphorus (mg/L)	K (mg/L)	Mg (mg/L)	pH	Na (mg/L)
1	Soil chemical	75.60	1.00	40.10	210.40	0.36	2.70

Table 3. Baseline Analysis for soil physical properties

S/N	Sample identify	Silt	Sand	Clay	Bulk density	Porosity	Particle density
1	Soil physical	0.11	95.60	40.10	1.50	0.36	5.80

2.4. *Experimental Design*

A Complete Randomize Design (CBD) was employed for this experiment, following the approach outlined by Pere (1981) and modified by *Amadi et al.* (2018). Soil samples were homogenized and weighed using a Setra 480S weighing balance (USA), calibrated in kilograms. Two kilograms (2 kg) of the homogenized soil were placed into planting bags, which were then organized into seven batches. The treatments for the batches were as follows: 2kg/CPL1, 2kg/CPL2, and 2kg/CPL3, which were treated with 100g, 200g, and 300g of cassava waste, respectively; and 2kg/PLM1, 2kg/PLM2, and 2kg/PLM3, which received 100g, 200g, and 300g of poultry manure, respectively. The control batch (CCPL) was treated with no cassava peel or poultry waste. After a two-week acclimatization period, seedlings of *Abelmoschus esculentus* (okra) were transplanted into the planting bags corresponding to each treatment. Each treatment had six replicates. The experiment was monitored over a period of two months, with plants being watered twice daily (morning and evening) using a watering can. Key morphological traits, including plant height, leave number, leaf length, and leaf width were measured at weekly intervals.

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Published online: 28th January, 2025

2.5. *Laboratory analysis*

The analysis utilized materials selected by the Institute of Tropical Agriculture (IITA, 1991). Soil texture was determined through the hydrometric method involves soil particles suspension in water and allowing them to settle according to their size and weight, facilitating the separation of particles (Stewart *et al*., 1974). Soil pH was measured using a HANNA HI8314 pH meter. Phosphorus and nitrogen levels were assessed using the oxidation, ascorbic acid, and Kjeldahl digestion methods as described by Stewart *et al*. (1974). Potassium content was quantified via atomic absorption spectrophotometry following digestion using Bray No. 1 solution. Soil bulk and particle densities were measured using the procedure outlined by Blake and Hartge (1986). Porosity was calculated using the formula: $\% Ø = (1 - BD/PD) \times 100$, where Ø represents porosity, BD is bulk density, and PD is particle density. Magnesium (Mg^{2+}) and nitrate (N) contents were determined by atomic absorption spectrometry (AAS) following digestion, consistent with standard analytical practices.

For morphological assessments, plant height was measured weekly from the base of the stem at the soil surface to the tip of the highest leaf, using a measuring tape to monitor growth progress. Leaf length was recorded from the tip of the leaf to the base where the blade meets the petiole, while leaf width was measured at the widest point of the leaf, perpendicular to the midrib, using a ruler. Only fully developed leaves were measured to ensure accuracy. The number of leaves was counted based on fully emerged, healthy leaves, with counts recorded at regular intervals to assess plant development.

2.6. *Data Analysis*

From the generated data, the treatment means and standard deviations were calculated for each monitored assessment variable. A two-way ANOVA was conducted to identify significant differences between treatment means. Significant differences were further examined using Fisher's LSD test to pinpoint specific treatment means responsible for the observed differences at a 5% probability level ($p = 0.05$). Statistical analysis was performed using SAS version 20 (2002) for Windows, and the results were presented in a vertical column chart and a composite table.

3.0. RESULTS

3.1. *Effects of cassava waste on soil nutrient properties*

The treatment with 200g of cassava peel yielded the highest mean soil potassium (35.3 ± 2.30^a) significantly different (*P=0.05*) from control (24.26 ± 0.05^c). The highest mean magnesium level (67.6 ± 0.57^a) was observed in 100g of cassava peel, significantly different (*P=0.05*) from the lowest (61.0 ± 0.57^c) in 300g and control. The 300g cassava peel treatment had significantly (*P=0.05*) the highest mean nitrogen level (5.50 ± 0.00^a), than the control with the lowest (2.33 ± 0.01^d) mean value and other treatment.

When compared within treatment 200g of cassava peel treatment recorded highest mean sodium level (13.20 ± 0.34^a) in the soil, indicating a notable increase compared to other treatments. In contrast, the control group exhibited the highest sodium concentration across treatment (20.76 ± 0.05^d). The difference in sodium levels between the 200g treatment and the control was statistically significant, confirming that the 200g cassava peel treatment effectively increased soil sodium content, with significance established at *P=0.05*.

The treatment with 300g of cassava peel significantly (*P=0.05*) yielded the highest mean phosphorus level (15.53 ± 0.05^a), than the control (0.22 ± 0.05^d) and other treatments. The 100g cassava peel treatment recorded the highest soil pH (6.20 ± 0.00^a), significantly different (*P=0.05*) from the 300g treatment (5.53 ± 0.11^d) and control levels (Table 4).

3.2. *Effect of Poultry Manure on Soil Nutrient Properties*

The increase in soil potassium concentration 300g poultry manure treatment (4.66 ± 0.20^a) was significantly (*P=0.05*) higher than the control soil potassium (2.36 ± 0.57^c). The control treatment exhibited the highest mean magnesium content (0.34 ± 0.01a) significantly different (*P=0.05*) from the lowest magnesium concentration (0.23 ± 0.01d) at 200g poultry manure treatment. The highest mean nitrogen levels of 6.33 ± 0.05^a and 6.33 ± 0.12^a for both the 200g and 300g poultry manure treatments were respectively recorded and significantly different (*P=0.05*) from nitrogen content (4.76 ± 0.05^c) at the control level. The mean sodium concentration (38.6 ± 0.34^a) was high at the 300g poultry manure treatment, while the lowest sodium content (30.36 ± 0.11^c) was recorded at 200g treatment with significant difference (*P=0.05*). Phosphorus concentration (3.83 ± 0.05^a) was significantly higher at 200g poultry manure treatment than the control (1.70 ± 0.10^c). The highest mean soil pH (6.83 ± 0.06^a),

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Article History:
Received 14TH November.2024
Received in revised form: 14TH January, 2025
Accepted 25th January, 2025
Published online: 28th January, 2025

was recorded at 300g poultry manure treatment while the lowest pH (3.33 ± 0.06^{d}) was revealed at 100g treatment with significant difference (*P=0.05*) (Table 4).

Table 4. Effects of cassava peel and poultry manure on soil nutrient levels.

Parameters	Cassava peels Treatment					Poultry Treatment			
	Control	100g	200g	300g	LSD 5%	100g	200g	300g	LSD 5%
K	24.26± 0.05^{c}	32.34±0.01^{b}	35.30 ± 2.30^{c}	33.46±0.05^{ba}	2.17	4.30 ± 0.10^{b}	4.33 ± 0.57^{b}	4.66 ± 0.20^{a}	0.23
Mg	64.60 ± 2.30^{b}	61.00 ± 1.73^{c}	64.60 ± 1.50^{b}	67.60 ± 0.57^{a}	2.97	0.33 ± 0.10^{b}	0.23±0.01^{d}	0.24 ± 0.01^{c}	0.01
N	2.33± 0.01^{d}	4.71 ± 0.01^{c}	5.25 ± 0.05^{b}	5.50 ± 0.00^{a}	0.06	5.33 ± 0.05^{b}	6.33 ± 0.10^{a}	6.33 ± 0.12^{a}	0.14
Na	20.76± 0.05^{d}	13.20 ± 0.34^{a}	12.33±0.57^{b}	10.06 ± 0.11^{c}	0.65	38.6 ± 0.34^{a}	30.36±0.11^{c}	38.60 ± 0.34^{a}	0.65
P	0.22 ± 0.05^{d}	13.32 ± 0.02^{c}	13.80±0.11^{b}	15.53 ± 0.05^{a}	0.59	2.43 ± 0.05^{b}	3.83 ± 0.05^{a}	3.56 ± 0.28^{a}	0.29
pH	5.76 ± 0.67^{b}	6.20 ± 0.00^{a}	6.10 ± 0.17^{a}	5.53 ± 0.11^{c}	0.20	5.46±0.12^{c}	3.33±0.06^{d}	6.83 ± 0.06^{a}	0.13

3.3. *Effects of organic amendment on growth parameter of Abelmoschus esculentus*

The results (Table 5) showed the impact of different levels of organic amendments on various morphological properties of plants. Cassava treatment produced the highest plant growth at 2 weeks with 100g and at 4 weeks with 200g of soil amendment. There was significant difference between and within treatment at *P=0.05*.With poultry treatment, the greatest plant height was recorded in the 100g poultry-treated soil at both 2 and 4 weeks. The number of leaves increased in soil treated with 300g of cassava at 2 and 4 weeks, while the highest increase in leaf number was observed in the 200g poultry-treated soil at both periods. Leaf length was found to increase in control soil at 2 weeks and in soil treated with 300g of cassava at 4 weeks. The highest leaf length increase occurred in 100g poultry-treated soil at 2 weeks and in 300g poultry-treated soil at 4 weeks. Leaf width increased in the control soil at 2 weeks and in 300g cassava-treated soil at 4 weeks. With poultry treatment, the highest leaf width was recorded in 200g poultry-treated soil at both 2 and 4 weeks. There was significant difference between and within treatment at *P=0.05*.

Table 5. Effects of organic amendment on growth parameter of *Abelmoschus esculentus*

parameters	Duration	Cassava peel treatment					Poultry manure treatment			
		Control	100g	200g	300g	LSD %5	100g	200g	300g	LSD %5
H	2wk	7.63 ± 0.32^{ba}	7.96±0.89^{a}	6.00± 0.86^{bc}	5.00± 1.30^{c}	1.72	7.66± 2.25^{a}	7.00± 0.50^{ba}	4.80 ± 0.72^{b}	2.29
	4wk	11.63±0.321^{b}	21.30±6.60^{a}	26.00± 0.87^{a}	25.00± 1.30^{a}	0.01	17.60±2.25^{a}	17.30± 1.04^{a}	14.80±0.72^{b}	2.45
NL	2wk	2.66± 1.54^{b}	3.00 ± 0.00^{b}	3.00± 0.00^{b}	5.00 ± 0.00^{a}	1.09	3.00 ± 0.00^{a}	3.00 ± 0.00^{a}	2.66 ± 0.57^{a}	0.54
	4wk	6.70± 0.57^{c}	7.00± 1.0^{cb}	8.33 ± 0.57^{b}	13.60± 1.15^{a}	1.63	23.00 ± 0.00^{c}	29.60 ± 5.77^{b}	42.60 ± 0.57^{a}	5.46
LL	2wk	3.23± 0.58^{a}	2.50 ± 0.10^{b}	2.70 ± 0.12^{ba}	2.30 ± 0.30^{b}	0.63	2.93 ± 0.40^{ba}	2.76± 0.15^{ba}	2.40 ± 0.36^{b}	0.76
	4wk	8.56± 0.49^{ba}	6.50 ± 0.10^{c}	7.33± 0.64b^{c}	10.30± 1.90^{a}	2.01	12.93± 0.40^{b}	16.10± 5.88^{b}	22.06± 0.92^{a}	5.65
LW	2wk	3.10± 0.45^{a}	2.66± 0.15^{a}	2.73± 0.21^{a}	2.56 ± 0.40^{a}	0.62	2.76± 0.61^{a}	2.86 ± 0.30^{a}	2.53± 0.47^{a}	0.89
	4wk	8.43± 0.21^{d}	9.60± 0.15^{c}	11.73± 0.21^{b}	12.56± 0.40^{a}	0.49	22.76± 0.61^{a}	27.86± 5.48^{a}	25.53± 0.47^{a}	5.23

NOTE: H: plant height, Nl: number of leaves, LL: leaf length, Lw: Leaf width.

4. DISCUSSION

Soil fertility serves as the cornerstone of agricultural productivity and sustainable food systems, directly influencing crop health, yield, and the resilience of farming systems. However, conventional agricultural practices such as the overuse of synthetic fertilizers, monocropping, and continuous intensive farming have contributed to widespread soil degradation. This degradation manifests as nutrient depletion, reduced soil organic matter, declining crop productivity, and a vulnerability to erosion and climate extremes. In response to these challenges, organic soil

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Article History:
Received 14TH November.2024
Received in revised form: 14TH January, 2025
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Published online: 28th January, 2025

amendments like cassava peel and poultry manure offer sustainable and eco-friendly solutions. These amendments not only replenish vital nutrients but also enhance soil structure and biodiversity through the gradual release of essential nutrients. Cassava peel, abundant in potassium, phosphorus, and carbohydrates, is a valuable organic material that improves soil nutrient balance, aiding in root development and water retention. Similarly, poultry manure is rich in nitrogen, phosphorus, and organic matter, fostering microbial activity and nutrient availability critical for healthy plant growth. Together, these organic inputs present a viable alternative to synthetic fertilizers, promoting long-term soil health, environmental stewardship, and sustainable food production practices (Amoakwah *et al*., 2020). This study evaluates the comparative efficacy of cassava peel and poultry manure in enhancing soil nutrient levels and promoting the growth of *Abelmoschus esculentus.* Table 1 demonstrates a notable effect of cassava peel on soil potassium levels, with the highest concentration observed in the 200g treatment, while the control displayed the lowest. The elevated potassium levels can be attributed to the potassium-rich nature of cassava peel, which releases nutrients gradually as it decomposes. This finding corroborates Ojeniyi *et al.* (2012), highlighting the ability of cassava peel to increase soil potassium through natural decomposition processes. Potassium is a critical nutrient for plant metabolism, supporting photosynthesis, enzyme activation, and water regulation, which collectively contribute to enhanced crop performance (Olaniyi *et al*., 2007). Furthermore, the 300g cassava peel treatment yielded the highest phosphorus concentration, a result consistent with Adediran *et al*. (2005), who found that cassava peel amendments can enrich soil phosphorus over time. Phosphorus is essential for root development, energy transfer, and the formation of DNA and RNA in plants, all of which are vital for robust plant growth and productivity. Thus, the integration of cassava peel not only supplies immediate nutrient requirements but also establishes a nutrient-rich soil environment that supports long-term soil fertility and plant health. By leveraging the natural nutrient composition of cassava peel, particularly its potassium and phosphorus content, this study underscores the potential of cassava peel as an organic amendment. It provides a sustainable pathway for soil enhancement, reducing reliance on synthetic fertilizers while maintaining or even improving crop productivity.

Phosphorus is essential for root development and energy transfer within plants, directly influencing plant vigor, growth, and productivity. Nitrogen, another crucial nutrient, showed a progressive increase in soil content with cassava peel treatments, with the 300g application yielding the highest nitrogen concentration. Although cassava peel itself is not particularly nitrogen-rich, its organic matter content stimulates microbial activity, facilitating nitrogen mineralization from the soil's organic pool, as reported by Adebayo *et al*. (2019). This microbial-driven increase in nitrogen is vital for robust leaf and stem development, particularly beneficial for nitrogen-demanding crops like okra.

In contrast, poultry manure, renowned for its substantial nitrogen and phosphorus content, had a significant impact on soil nitrogen and phosphorus levels. Table 1 shows that the highest soil nitrogen level was recorded with the 300g poultry manure treatment, corroborating Akanbi *et al.* (2010), who observed that poultry manure application, can lead to remarkable increases in soil nitrogen. Nitrogen is essential for chlorophyll synthesis, protein formation, and overall plant metabolism, thereby enhancing crop growth, leaf expansion, and productivity. Phosphorus levels were also markedly increased with poultry manure application, with the 200g treatment producing the highest phosphorus concentration. This result corroborates studies by Ayeni *et al*. (2022), which demonstrated the efficacy of poultry manure in enriching soil phosphorus. Phosphorus availability is vital for energy transfer, photosynthesis, and the development of a healthy root system, all of which contribute to improved plant resilience and overall health. The enriched phosphorus in poultry manure further supports root establishment and flowering, which are key for maximizing okra yield and quality. These findings highlight the differential benefits of cassava peel and poultry manure: cassava peel supports soil potassium and indirectly enhances nitrogen availability through organic decomposition, while poultry manure serves as a potent source of readily available nitrogen and phosphorus. Together, these organic amendments offer a balanced, sustainable approach to nutrient management, promoting soil fertility, crop health, and productivity without reliance on synthetic fertilizers.

In assessing *Abelmoschus esculentus* growth parameters, cassava peel and poultry manure exhibited distinct influences on plant development, particularly evident in Table 2 at 4 weeks. The cassava peel treatment at 200g produced the tallest plants, significantly higher than the control. This suggests that the high potassium content in cassava peel may have played a crucial role in shoot development, as potassium is integral for water regulation, nutrient uptake, and overall plant vigor. In contrast, poultry manure showed notable effects on plant height at lower application rates, with the 100g and 200g treatments yielding taller plants than the 300g treatment. The rich nitrogen content in poultry manure generally supports strong vegetative growth, but at excessive levels, it may lead to nutrient imbalances, potentially stalling growth due to excess nitrogen or reduced soil pH (Adediran *et al*., 2004).

In terms of leaf development, poultry manure had a pronounced effect, with the 300g treatment achieving the highest leaf count at 4 weeks, as shown in Table 5. This aligns with findings by Ojeniyi and Adetunji (2006), which indicated that poultry manure accelerates leaf development due to its high nitrogen and phosphorus content,

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Article History:
Received 14TH November.2024
Received in revised form: 14TH January, 2025
Accepted 25th January, 2025
Published online: 28th January, 2025

both essential for chlorophyll production and cell division. In comparison, cassava peel recorded its highest leaf count with the 300g treatment as well, though this was still lower than the leaf production observed with poultry manure. This suggests that cassava peel may be more beneficial for enhancing root and shoot development than for promoting extensive leaf growth. Generally, poultry manure demonstrated greater efficacy in elevating soil nitrogen and phosphorus levels, supporting more vigorous leaf production and denser vegetative growth in okra. Cassava peel, while containing less nitrogen, was effective in increasing soil potassium and phosphorus levels, which contributed to taller plants and potentially enhanced root growth. The distinct nutrient profiles of each amendment provide complementary benefits for soil fertility: poultry manure's nitrogen-rich composition enhances vegetative growth, while the potassium content in cassava peel supports strong shoot and root structures. Integrating both amendments could offer a balanced approach to soil fertility management. By combining the nitrogen and phosphorus advantages of poultry manure with the potassium contributions from cassava peel, farmers can potentially optimize plant growth, achieving both robust vegetative growth and improved root and shoot development. This holistic approach to nutrient management could enhance okra productivity and overall soil health, providing a sustainable alternative to synthetic fertilizers while supporting a diversified and resilient agricultural system (Olowe *et al*., 2010).

5. CONCLUSION

This study highlights the unique and complementary effects of cassava peel and poultry manure on soil fertility and okra growth. Poultry manure, with its high nitrogen and phosphorus content, provides an immediate boost to soil fertility, supporting vigorous vegetative growth and enhanced leaf development in the short term. Conversely, cassava peel, rich in potassium and phosphorus, contributes to gradual but sustained improvements in soil nutrient levels, particularly beneficial for long-term soil health and steady plant growth. Conclusively, poultry manure is ideal for immediate nutrient supplementation, cassava peel offers valuable benefits for ongoing nutrient release and soil structure improvement. Together, these organic amendments present a sustainable alternative to synthetic fertilizers, each addressing distinct aspects of soil and plant health. Combining poultry manure for its immediate fertility benefits with cassava peel for sustained nutrient management may provide a balanced approach to achieving higher crop productivity and supporting soil health in the long term.

ACKNOWLEDGEMENTS

I sincerely appreciate everyone who, in various capacities, contributed to the success of this work. Your efforts have been invaluable, and I am deeply grateful for your involvement in this work.

CONFLICT OF INTEREST

Authors have declared that no competing interests exist.

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Article History:
Received 14TH November.2024
Received in revised form: 14TH January, 2025
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Published online: 28th January, 2025

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Article History:
Received 14TH November.2024
Received in revised form: 14TH January, 2025
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